Estimated Sea Otter Population Size in Glacier Bay

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Introduction

Nearshore marine communities support a wide array of commercially, recreationally and culturally valuable resources including plants, invertebrates, birds, and mammals. In order to understand, quantify and attribute cause to changes in these communities, it is imperative to understand primary sources of community structuring and of natural or background levels of variation in the ecosystem. The sea otter, once nearly extinct, is currently reoccupying previous habitat in much of the north Pacific, including Glacier Bay. The role of sea otters in structuring nearshore marine communities is recognized as significant, particularly among exposed rocky shorelines. However, much less is known of the effects of sea otter reintroduction into soft sediment habitats. It is now possible to examine effects of sea otter foraging as they begin to recolonize Glacier Bay National Park and Preserve in southeast Alaska, a predominantly soft bottom sediment community.

Various pieces of data are necessary to evaluate changes in nearshore marine communities and to allow careful determination of the causal role of sea otters in such changes. Information on the distribution and abundance of sea otters in and around Glacier Bay will provide a description of the spatial and temporal process of sea otter recolonization and provide the basis for study sites to evaluate changes in community structure before and after the effects of sea otters.

Surveys from boats and fixed-wing aircraft have been conducted to document sea otter distribution and relative abundance. In 1999, a more intensive survey of Glacier Bay was designed in conjunction with methodology developed from surveying sea otters in other parts of Alaska. This aerial survey design has several advantages over previous surveys: 1) stratified sampling maximizes sampling effort, 2) systematic transects sample evenly across strata, 3) bias is reduced by estimating the proportion of sea otters not detected, and 4) replication provides a more precise estimate of population size and reduces sampling error. Results of this survey provide a relatively unbiased estimate of population size, that can be used as a bench mark to evaluate future changes in population size. This survey is a cooperative project between the USGS/Alaska Biological Science Center and Glacier Bay National Park and Preserve.

Methods

Aerial survey methods follow those described in detail in Bodkin and Udevitz (1999) and consisted of two components: 1) strip transects and 2) intensive search units to estimate the probability of detection of otters along strips. Sea otter habitat was sampled in two strata, a high and a low density, distinguished by distance from shore and bathymetry. Survey effort was allocated proportional to expected sea otter abundance by systematically adjusting spacing of transects within each stratum. Transects 400 m wide were surveyed by a single observer at an airspeed of 65 mph (29 m/sec) and an altitude of 300 ft (91 m). Strip transect data included date, transect number, location, group size and group activity (diving or not diving). A group was defined as one or more otters separated by less than 4 m. Transect end points were identified by latitude/longitude coordinates in Arc Info and displayed visually in a aeronautical global positioning system (GPS) in the aircraft. Intensive searches were conducted systematically along strip transects to estimate the proportion of animals not detected during strip counts.

The survey design consisted of 18 strip transect scenarios constructed in a GIS (ARC/INFO) consisting of 3 possible high density sets of transects and 6 sets of low density transects. Transects were charted throughout Glacier Bay, but this survey focused on the lower bay (Fig. 1) since sea otters do not yet occur in the upper bay. The lower bay survey area included 272 km2 of high density stratum and 274 km2 of low density stratum. Five replicates were randomly selected from the 18 possible and surveyed by a single observer from a Bellanca Scout between 8 and 13 May 1999. Both the pilot and the observer had previous experience using the survey technique and were familiar with Glacier Bay. See Appendix A for a detailed description of the survey methods used.

Results

The five replicate surveys required 35 hours of flight time to complete, including transit to and from Bartlett Cove. The mean of four individual replicates yielded an adjusted population size estimate of 384 (SE = 111). The first replicate was excluded because it lacked the minimum amount of data needed to calculate a correction factor for sea otters not detected. Sea otter pups are combined with adults for population estimation because large pups are often indistinguishable from adults and small pups can be difficult to sight from aircraft. All group locations were digitized by survey into ARC/INFO coverages (Fig. 2).

Discussion

Sea otters are more evenly distributed throughout the lower bay than in prior survey years with concentrations near Leland Island, Boulder Island, and Point Carolus (Fig. 2). Because lower Glacier Bay encompasses the forefront of an expanding sea otter population, immigration and emigration are likely to be the major factors driving abundance estimates. Previous aerial and boat surveys, covering Glacier Bay as well as surrounding areas in Icy Strait and Cross Sound, have shown evidence of seasonal movements. This variation may explain why 410 adults and 73 pups were counted during an August 1998 boat survey in lower Glacier Bay.

The current survey design proved highly effective overall, but one component can be improved. High and low density strata were defined by a combination of criteria, including depth and distance from shore (Bodkin and Udevitz 1999). Although these criteria seem to predict sea otter habitat accurately, application of this technique in Prince William Sound has shown that strata modifications are sometimes necessary to include unique areas. These areas tend to occur where resting sea otters drift far from shore, over deep water. In Glacier Bay, one such area was identified in a triangle formed by South Marble, Leland, and Flapjack Islands. This region should be reclassified as a high density area and sampled accordingly in future surveys.

The number of sea otters occupying Glacier Bay is increasing rapidly, from a count of 5 in 1995 to nearly 400 in 1998 (Table 1). This increase is undoubtedly due to both immigration of adults and juveniles as well as reproduction by females in the Bay, evidenced by dependent pups. One adult female tagged in Port Althorp in 1998 was observed near South Marble Island in July 1999 with a dependant pup. Predation by sea otters on a variety of invertebrates, including several species of crab, clams, mussels, and urchins will likely have profound effects on the benthic community structure and function of the Glacier Bay ecosystem. Continuing sea otter surveys and studies of benthic communities will provide valuable information to those responsible for managing Park resources.

References

Bodkin, J.L., and M.S. Udevitz. 1999. An aerial survey method to estimate sea otter abundance. Pages 13-26 in G.W. Garner et al., editors. Marine Mammal Survey and Assessment Methods. Balkema, Rotterdam, Netherlands.

Table 1. Sea otter counts from aerial surveys in Cross Sound, Icy Straits and Glacier Bay, 1994-1999. Counts are presented as adults/ pups, and a period equals no data. The Scout is a Bellanca Scout and the 172 and 185 are Cessnas.

date	May 94	May 95	Mar 96	Aug 96	May 97	Mar 98	May 99
Aircraft	Scout	Scout	172	172	Scout	185	Scout
survey area							
Spencer-Pt Wimbledon	69/20	60/9	31/4	19/2	43/3	8	6
Pt Wimbledon-Pt. Dundas	37/1	23	18	52	24	52	27
Pt Dundas-Pt Gustavus	0	12/1	41/1	178/4	10	1	17
Glacier Bay Proper	**.**	**5**	**39**	**0**	**21**	**209**	**384***
Excursion Inlet	.	.	.	.	.	7	1
Pt Couverdon	.	.	.	.	.	2	.
Pt Gustavus-Porpoise Is.	29/0	94/1	73	2/1	161	8	18
Cannery Pt-Crist Pt	0	0	0	0	0	0	0
Crist Pt-Gull Cove	55	15/3	30/1	17/1	92/15	23	97/3
Lemesurier Is.	33/8	62/23	56/2	47/8	143/32	10	67/17
Gull Pt-Pt Lavina	77	81	48	141	94	3	90
Inian Is.	31/9	36/16	11/1	30/12	31/8	10	18/4
Pt Lavina-Column Pt	100/31	159/73	42/3	94/21	148/25	31	21/7
Total	**431/69**	**547/126**	**389/12**	**580/49**	**767/83**	**364**	**746/31**

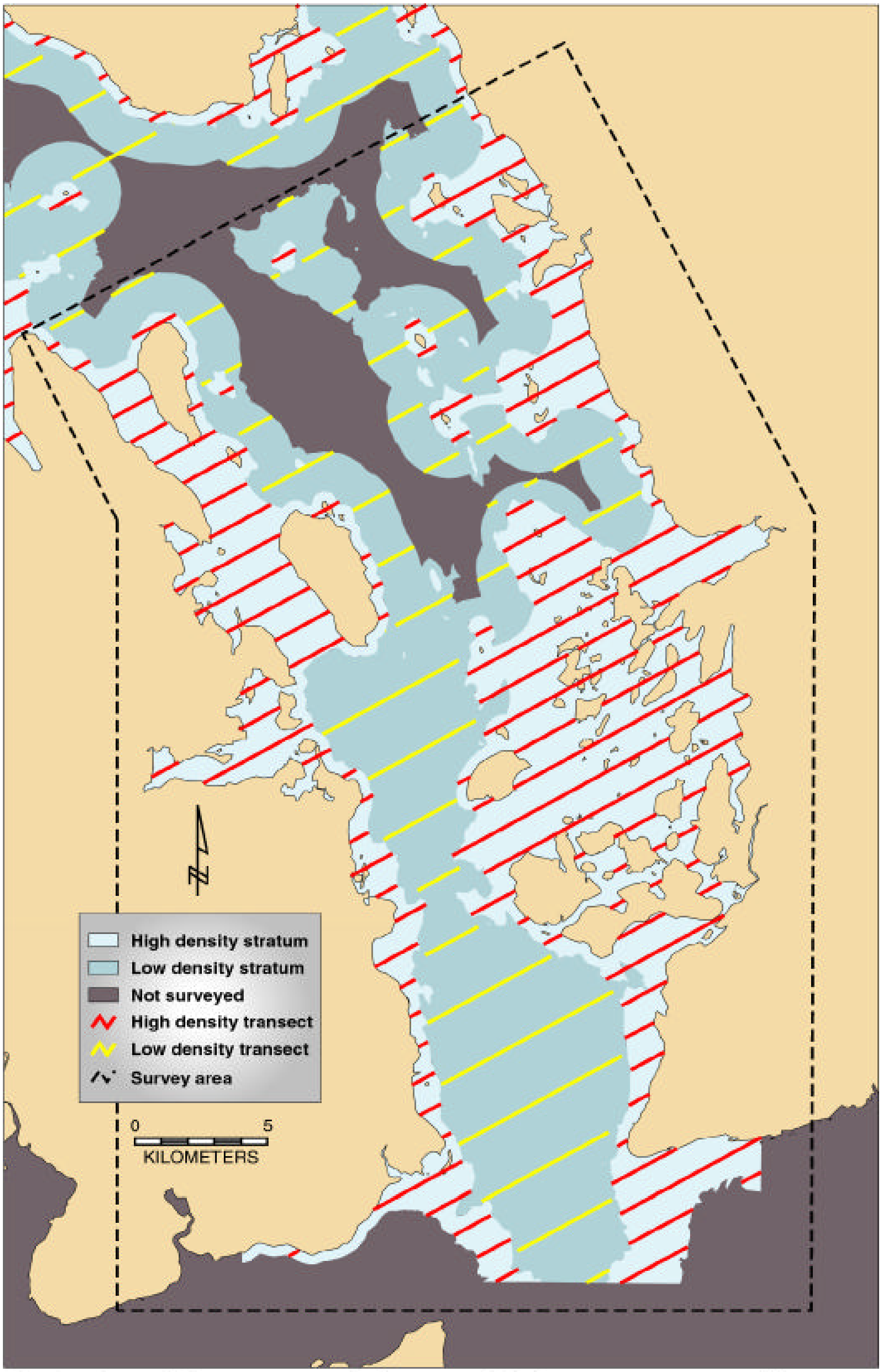

Fig. 1. One of four transect designs used during a sea otter aerial survey in Glacier Bay National Park, May 1999.

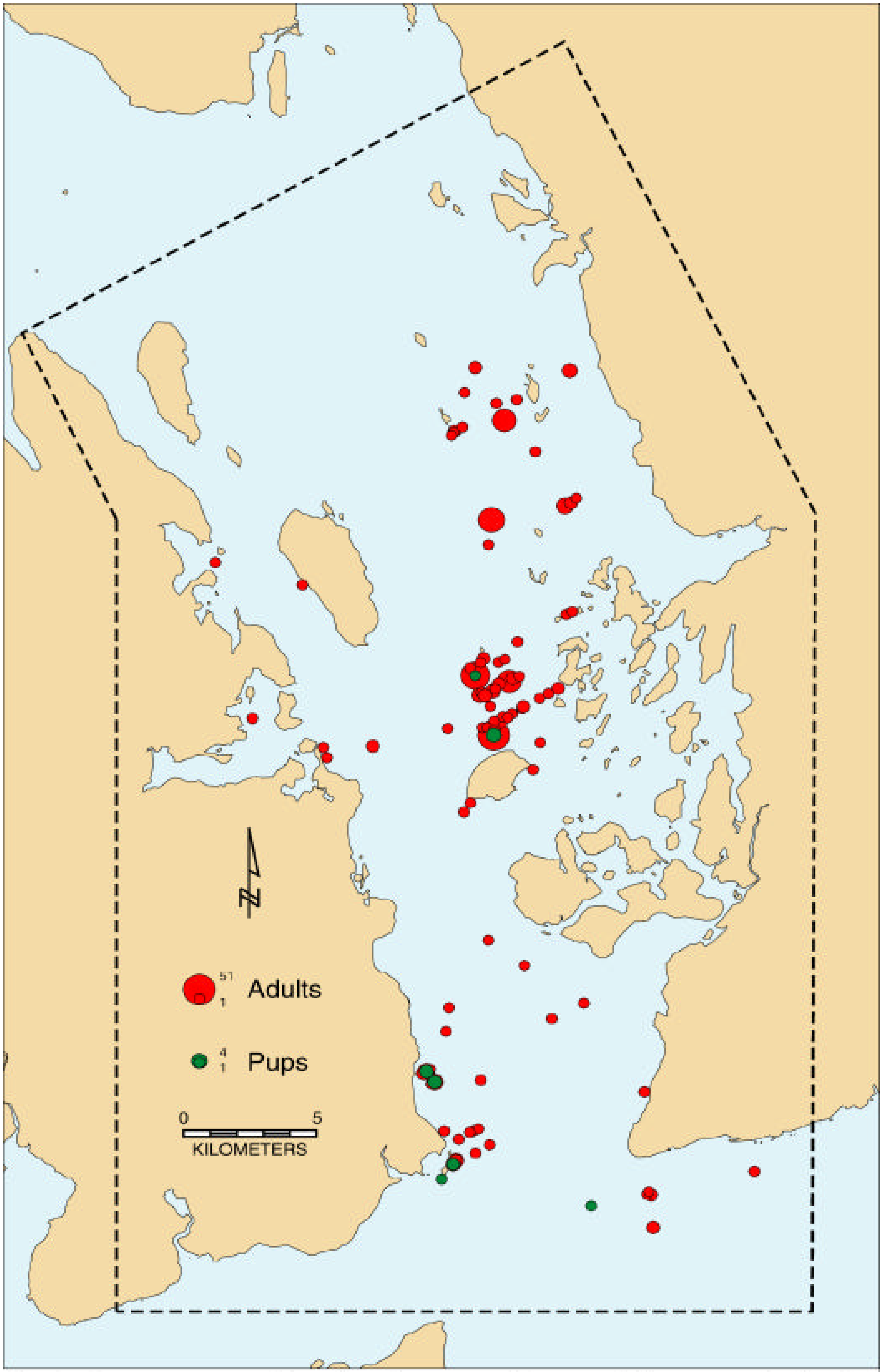

Fig 2. Sea otter group locations from 5 replicate aerial surveys in Glacier Bay National Park, May 1999.

SAMPLING PROTOCOL FOR SEA OTTER AERIAL SURVEYS

Overview of survey design

The survey design consists of 2 components: (1) strip transect counts and (2) intensive search units.

1) Strip Transect Counts

Sea otter habitat is sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. The high density stratum extends from shore to 400 m seaward or to the 40 m depth contour, whichever is greater. The low density stratum extends from the high density line to a line 2 km offshore or to the 100 m depth contour, whichever is greater. Bays and inlets less than 6 km wide are sampled entirely, regardless of depth. Transects are spaced systematically within each stratum. Survey effort is allocated proportional to expected otter abundance in the respective strata.

Prior to surveying a geographic area (e.g. College Fjord, Prince William Sound), the observer will determine which side of the transect lines (N, S, E, or W) has less glare. The side with less glare will be surveyed by a single observer in a fixed-wing aircraft. Transects with a 400 meter strip width are flown at an airspeed of 65 mph (29 m/s) and an altitude of 300 feet (91 m). The observer searches forward as far as conditions allow and out 400 m, indicated by marks on the aircraft struts, and records otter group size and location on a transect map. A group is defined as 1 or more otters spaced less than 3 otter lengths apart. Any group greater than 20 otters is circled until a complete count is made. A camera should be used to photograph any groups too large and concentrated to count accurately. The number of pups in a group is noted behind a slash (eg. 6/4 = 6 adults and 4 pups). Observation conditions are noted for each transect and the pilot does not assist in sighting sea otters.

2) Intensive Search Units

Intensive search units (ISU's) are flown at intervals dependant on sampling intensity*, throughout the survey period. An ISU is initiated by the sighting of a group and is followed by 5 concentric circles flown within the 400 m strip perpendicular to the group which initiated the ISU. The pilot uses a stopwatch to time the minimum 1 minute spacing between consecutive ISU's and guide the circumference of each circle. With a circle circumference of 1,256 m and an airspeed of 65 mph (29 m/s), it takes 43 seconds to complete a circle (e.g. 11 seconds/quarter turn). With 5 circles, each ISU takes about 3.6 minutes to complete. ISU circle locations are drawn on the transect map and group size and behavior is recorded on a separate form for each ISU. For each group, record number observed on the strip count and number observed during the circle counts. Otters that swim into an ISU post factum are not included and groups greater than 20 otters cannot initiate an ISU.

Behavior is defined as "whatever the otter was doing before the plane got there" and recorded for each group as either diving (d) or nondiving (n). Diving otters include any individuals that swim below the surface and out of view, whether traveling or foraging. If any individual(s) in a group are diving, the whole group is classified as diving. Nondiving otters are animals seen resting, interacting, swimming (but not diving), or hauled-out on land or ice.

* The targeted number of ISU's per hour should be adjusted according to sea otter density. For example, say we have an area that is estimated to take 25 hours to survey and the goal is to have each observer fly 40 "usable" ISU's; an ISU must have more than one group to be considered usable. Because previous data show that only 40 to 55% of the ISU's end up being usable, surveyors should average at least 4 ISU's per hour. Considering the fact that, one does not always get 4 opportunities per hour - especially at lower sea otter densities, this actually means taking something like the first 6 opportunities per hour. However, two circumstances may justify deviation from the 6 ISU's per hour plan:

1) If the survey is not progressing rapidly enough because flying ISU's is too time intensive, *reduce* the minimum number of ISU's per hour slightly

2) If a running tally begins to show that, on average, less than 4 ISU's per hour are being flown, *increase* the targeted minimum number of ISU's per hour accordingly.

The bottom line is this: each observer needs to obtain a preset number of ISU's for adequate statistical power in calculation of the correction factor. To arrive at this goal in an unbiased manner, observers must pace themselves so ISU's are evenly distributed throughout the survey area.

Appendix A.

Preflight

Survey equipment:

binder:
- random map set selections
- map sets (observer, pilot, & spare copies)
- strip forms (30)
- ISU forms (60)
- survey protocol
- Trimble GPS procedures
- data entry formats

laptop computer for data entry
floppy disk with transect waypoints
Solidstate data drive with power adaptor & interface cable
RAM cards with transect waypoints
RAM card spare batteries
low power, wide angle binoculars (e.g. 4 X 12)
clipboards (2)
pencils
highlighter pen
stopwatch for timing ISU circles
35 mm camera with wide angle lens
high-speed film
survival suits

Airplane windows must be cleaned each day prior to surveying.

Global Positioning System (GPS) coordinates used to locate transect starting and end points, must be entered as waypoints by hand or downloaded from an external source via a memory card.

Electrical tape markings on wing struts indicate the viewing angle and 400 m strip width when the aircraft wings are level at 300 feet (91.5 m) and the inside boundary is in-line with the outside edge of the airplane floats.

The following information is recorded at the top of each transect data form:

Date - Recorded in the DDMMMYY format.
Observer - First initial and up to 7 letters of last name.
Start time - Military format.
Aircraft - Should always be a tandem seat fixed wing which can safely survey at 65-70 mph.
Pilot - First initial and up to 7 letters of last name.

Area - General area being surveyed.

Observation conditions
Factors affecting observation conditions include wind velocity, seas, swell, cloud cover, glare, and precipitation. Wind strong enough to form whitecaps creates unacceptable observation conditions. Occasionally, when there is a short fetch, the water may be calm, but the wind is too strong to allow the pilot to fly concentric circles. Swell is only a problem when it is coupled with choppy seas. Cloud cover is desirable because it inhibits extreme sun-glade. Glare is a problem that can usually be moderated by observing from the side of the aircraft opposite the sun. Precipitation is usually not a problem unless it is extremely heavy.

Chop (C) and glare (G) are probably the most common and important factors effecting observation conditions. Chop is defined as any deviation from flat calm water up to whitecaps. Glare is defined as any amount of reflected light which may interfere with sightability. After each transect is surveyed, presence is noted as C, G, or C/G and modified by a quartile (e.g. if 25% of the transect had chop and 100% had glare, observation conditions would be recorded as 1C/4G). Nothing is recorded in the conditions category if seas are flat calm and with no glare.

Observer fatigue
To ensure survey integrity, landing the plane and taking a break after every 1 to 2 hours of survey time is essential for both observer and pilot. Survey quality will be compromised unless both are given a chance to exercise their legs, eat, go to the bathroom, and give their eyes a break so they can remain alert.

Vessel activity
Areas with fishing or recreational vessel activity should still be surveyed.

Special rules regarding ISU's
1. **Mistaken identity** - When an ISU is mistakenly initiated by anything other than a sea otter (e.g. bird, rock, or floating debris), the flight path should continue for one full circle until back on transect. At this point the ISU is to be abandoned as if it was never initiated and the normal fight path is resumed.

2. **Otters sighted outside an ISU -** Otters sighted outside an ISU which are noticed during ISU circles are counted only when the ISU is completed, normal flight path has been resumed, and they are observed on the strip.

Unique habitat features

Appendix A.

Local knowledge of unique habitat features may warrant modification of survey protocol:

1. **Extensive shoaling or shallow water (i.e. mud flats)** may present the opportunity for extremely high sea otter densities with groups much too large to count with the same precision attainable in other survey areas. Photograph only otters within the strip or conduct complete counts, typically made in groups of five or ten otters at a time. Remember, groups >20 cannot initiate an ISU.

   Example: Orca Inlet, PWS. Bring a camera, a good lens, and plenty of film. Timing is important when surveying Orca Inlet; the survey period should center around a positive high tide - plan on a morning high tide due to the high probability of afternoon winds and heavy glare. Survey the entire area from Hawkin's cutoff to Nelson Bay on the same high tide because sea otter distribution can shift dramatically with tidal ebb and flow in this region.

2. **Cliffs** - How transects near cliffs are flown depends on the pilot's capabilities and prevailing weather conditions. For transects which intersect with cliff areas, including tidewater glaciers, discuss the following options with the pilot prior to surveying.

   In some circumstances, simply increasing airspeed for turning power near cliffs may be acceptable. However, in steep/cliff-walled narrow passages and inlets, it may be deemed too dangerous to fly perpendicular to the shoreline. In this case, as with large groups of sea otters, obtain complete counts of the area when possible.

   In larger steep-walled bays, where it is too difficult or costly to obtain a complete count, first survey the entire bay shoreline 400 m out. Then survey the offshore transect sections, using the 400 m shoreline strip just surveyed as an approach. Because this is a survey design modification, these data will be analyzed separately.

   Example: Herring Bay, PWS. Several high cliffs border this area.
   Example: Barry Glacier, PWS. Winds coming off this and other tidewater glaciers may create a downdraft across the face. The pilot should be aware of such unsafe flying conditions and abort a transect if necessary.

3. **Seabird colonies** - Transects which intersect with seabird colonies should be shortened accordingly. These areas can be buffered for a certain distance in ARC dependant on factors such as colony size, species

composition, and breeding status.

Example: Kodiak Island. Colonies located within 500 m of a transect AND Black-legged Kittiwakes > 100 OR total murres > 100 OR total birds > 1,000 were selected from the seabird colony catalog as being important to avoid.

5. **Drifters** - During calm seas, for whatever reason - possibly a combination of ocean current patterns and geography - large numbers of sea otters can be found resting relatively far offshore, over extremely deep water, miles (up to 4 miles is not uncommon) from the nearest possible foraging area.

Example: Port Wells, PWS. Hundreds of sea otters were found scattered throughout this area with flat calm seas on 2 consecutive survey years. As a result, Port Wells was reclassified and as high density stratum.

4. **Glacial moraine** - Similar to the drifter situation, sea otters may be found over deep water on either side of this glacial feature.

Example: Unakwik, PWS. Like Port Wells, Upper Unakwik was reclassified as high density stratum.

Planning an aerial survey

Several key points should be considered when planning an aerial survey:

1) Unless current sea otter distribution is already well known, it is well worth the effort to do some reconnaissance. This will help define the survey area and determine the number of observers needed, spacing of ISU's, etc.

2) Plan on using 1 observer per 5,000 otters.

3) Having an experienced technical pilot is extremely important. Low level flying is, by nature, a hazardous proposition with little room for error; many biologists are killed this way. While safety is the foremost consideration, a pilot must also be skilled at highly technical flying. Survey methodology not only involves low-level flying, but also requires intimate familiarity with a GPS and the ability to fly in a straight line at a fixed heading with a fixed altitude, fixed speed, level wings, from and to fixed points in the sky. Consider the added challenge of flying concentric 400 meter circles, spotting other air traffic, managing fuel, dealing with wind and glare, traveling around fog banks, listening to radio traffic, looking at a survey map, and other

distractions as well. Choose the best pilot available.